Global Validation of EOS LAI and FPAR Products
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On 10-11 October, 1998, approximately 30 scientists met at Boston University to further plans for validating the EOS-AM LAI, FPAR and NPP products. The group included members of the MODIS Land (MODLAND), Interdisciplinary Science (IDS), and AM-1 Validation teams, as well as community experts. The goal was to develop both a focused 1-year implementation plan as well as a longer term ramp-up strategy. Five key topics were discussed, including 1) general needs and responsibilities, 2) auxiliary *in situ* parameters, 3) validation sites, 4) scaling field data up, and 5) dissemination of validation data and information. Below is a brief background, followed by a summary of the presentations, discussions and conclusions of this meeting.

Background

Leaf area index (LAI) and the fraction of photosynthetic radiation absorbed by vegetation (FPAR) are important land characteristics used to parameterize and validate models of ecosystem functioning, surface-atmosphere transfer, agricultural yield, net primary production and other environmental processes (Sellers and Schimel, 1993, Global and Planetary Change, 7:279-297). The international community has therefore deemed these parameters important for climate research (see GCOS and GTOS URLs in Table 3 for reference information), and endorse their operational long term monitoring (see GOFC URL in Table 3). Consequently, these parameters are a high priority for the EOS AM platform. Upon AM launch, LAI and FPAR data will be produced, at relatively high temporal resolution (daily through yearly), through both the MODIS and MISR product chains independently. NPP will be produced by MODIS. Later, single LAI and FPAR products from the AM platform will be produced once the most beneficial approach for fusing the data streams becomes clear.

To date, end-users of satellite data have had to rely on unvalidated LAI and FPAR products. The EOS Project, however, is supporting validation through its instrument teams and validation investigators (see URL in Table 3). In addition to quantifying the accuracy of EOS algorithms, this will greatly benefit modelers by providing uncertainty estimates alongside the EOS products. As with the design of the products themselves, a close dialogue is now needed between the field data collectors, the EOS algorithm developers, and the end-user community to ensure that the validation data are collected and packaged appropriately for greatest effectiveness. A significant step in this direction occurred with the SWAMP Validation Workshop (December, 1997), which exposed critical issues for global LAI/FPAR/NPP validation (Justice et al., 1998, Earth Observer, 10(3):55-60). The present meeting used recommendations from the SWAMP meeting as a starting point.

LAI/FPAR Product Description and Field Data Network

Recent advances in the MODLAND LAI/FPAR algorithm, led by Ranga Myneni (see URL in Table 3), translate uncertainty in the input fields (e.g., land cover class, surface bidirectional reflectance) into a probability distribution solution. This approach accounts for the likelihood of multiple solutions to the inverse problem given "perfect" input reflectances, then assumes additional estimation error resulting from true uncertainties in input reflectances. This approach both bounds the accuracy with which field validation data need be collected (and hence the collection method itself), and provides new measures for algorithm performance during validation.

At the meeting, Myneni proposed that two levels of validation occur: scale-independent validation of the stand-alone algorithm and scale-dependent validation of the LAI/FPAR product. This strategy allows confidence to develop in the algorithm using multiple fine-scale sample points at a single geographical test site, in addition to the more limited ability to validate the coarser-scale products at that site. Both point value and value distribution tests were proposed.

Responsibility for this validation will be shared between the MODIS and MISR instrument teams and the AM-1 Validation Investigators. However, for global validation, it is recognized that greater resources and coordination are required than are currently recruited. Thus, MODLAND is applying significant effort to developing EOS-wide validation protocols and encouraging participation by community data collectors and product users. Meeting participants extensively discussed potential synergy with existing measurement networks, including FLUXNET and Long Term Ecological Research (LTER) sites (see URLs in Table 3). This synergy may involve both post-launch measurements and historical data sets.

A possible model for assimilating data from such varied sources was outlined by Leonard Brown of the Canadian Centre for Remote Sensing, who is helping coordinate a federated LAI collection network in Canada. Brown reported that although significant effort was required to coordinate and maintain the network, most researchers were willing to collect data as part of their perceived scientific obligations. Further, Brown suggested the Canadian data, available for roughly 10 sites for 1-2 years, could be made available to the EOS Validation Program. MODLAND validation personnel will pursue this collaboration in the coming year.

Validation Sites

Global validation requires field data from a range of sites representing a logical subset of the Earth's land covers. Meeting participants agreed that the EOS Land Validation Core Sites should be emphasized for this purpose (see URL in Table 3)These sites are foci for EOS AM and Landsat 7 land validation activities, and are high priority data acquisition and product generation targets. They are expected to facilitate both validation and early EOS science. The sites typically have a history of in-situ and remote observations, and can expect long-term preservation. Centralized WWW-based archiving of ASTER, MISR, MODIS and Landsat 7 ETM+ products in relatively easy-to-use formats are planned for these sites.

Because the Core Site network is in its infancy, meeting participants agreed that LAI and FPAR validation should be planned only at sites for which firm commitments to data collection have been secured. However, several participants volunteered to collect data at non-Core sites. These "product-specific" validation sites, together with the participating Core sites, are listed in Table 1. The list provides at least two representatives from each of the six vegetated biome types recognized by the MODLAND LAI algorithm. Participants agreed that initially at least seasonal (4 times/yr) in situ LAI/FPAR assessments were required for product validation.

Table 1

Name	Country	Biome	EOS Core Site	Investigator
USDA BARC, MD	U.S.	broadleaf cropland	X	Liang
Bondville, IL	U.S.	broadleaf cropland	X	BigFoot
Gainesville, FL	U.S.	broadleaf cropland		Craig
Tapajos	Brazil	broadleaf forest	X	Asner
Hawaii	U.S.	broadleaf forest		Asner
Harvard Forest, MA	U.S.	broadleaf forest	X	BigFoot
Park Falls, WI	U.S.	broadleaf forest	X	Gower
Uardry	Australia	grassland	X	Hook
Osage, OK	U.S.	grassland		Walter-Shea
Konza, KS	U.S.	grassland	X	BigFoot
East Anglia	England	grassland	X	Barnsley
Vernon,TX	U.S.	grassland		Asner
BOREAS NSA	Canada	needleleaf forest	X	BigFoot
Cascades, OR	U.S.	needleleaf forest	X	Law
EMATREF	France	needleleaf forest		Roujean
Yaqui Valley	Mexico	shrubland		Asner
San Pedro Basin/ SALSA, AZ	U.S.	shrubland	X	Qi
Skukuza	South Africa	shrubland/woodland	X	Privette
New Zealand Network	New Zealand	various		Brown
Canada Network	Canada	various		Chen
Mongu	Zambia	woodland	X	Privette
Cerrado	Brazil	woodland		Asner

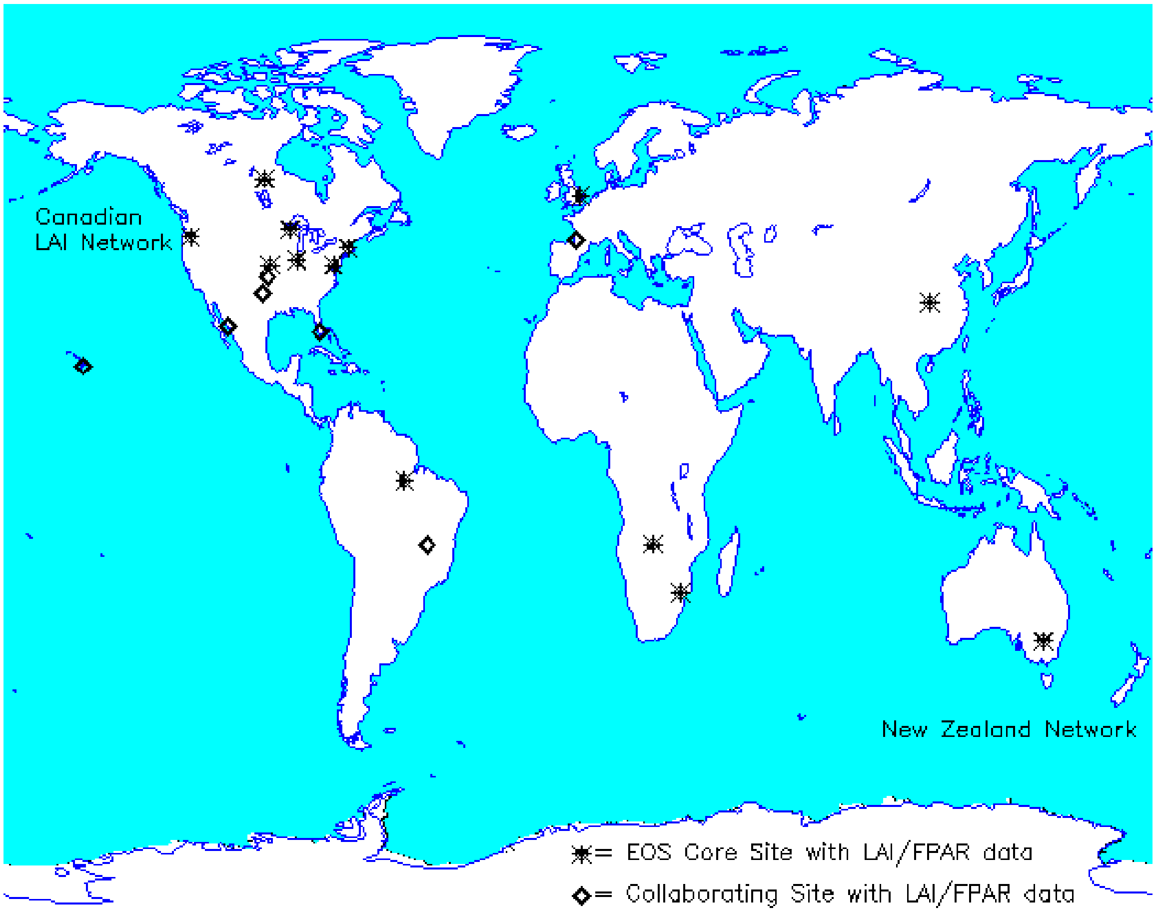

Fig. 1 EOS Land Validation Core Sites and collaborating sites being used for Year 1 LAI/FPAR product validation.

Auxiliary Measurements

Although product validation can be conducted with only LAI and FPAR field data, a prioritized list of ancillary measurements needed for algorithm validation was developed under Myneni's lead. Myneni emphasized that not all listed variables are necessary for this task, however any such measurements would be useful. The measurements are shown in Table 2 in order of decreasing importance.

Table 2

Land Cover Variable or Characteristic
canopy multispectral reflectance (nadir or bidirectional)
leaf spectra (reflectance and transmittance)
background nadir spectral reflectance (soil + litter)
fraction of areal vegetation cover
vegetation crown allometry (height, width, gap)
phenology (green-up, mature, senescent stage)
vegetation composition (either by species or structural type)
wet or dry status
fraction of non-photosynthesizing vegetation (at min. photosynthetic activity stage)
meteorological data (minimum set)

Scaling

A consistent and troubling problem for land product validation is the appropriate scaling of point field measurements to the coarse resolution of satellite products. Several presentations addressed this topic. Among the most encouraging was the newly formed BigFoot initiative (formerly MODLERS; see URL in Table 3). Warren Cohen and Dave Turner outlined BigFoot's plans to provide MODLAND validation data, as well as develop 5 km x 5 km gridded models (25 m and 1 km grids) around FLUXNET tower sites. BigFoot will initially focus efforts at four EOS Core Sites (BOREAS NSA, Harvard Forest, Bondville, and Konza). BigFoot will measure and scale up LAI, FPAR, NPP and landcover maps to appropriate resolutions for EOS validation. A combined program of field data collection, aircraft overflights and fine resolution satellite image acquisitions will be used. BigFoot will also attempt to characterize and parameterize the relationship between the measured NEE values and the MODLAND NPP product. This pathfinding activity will test various scaling methodologies and work with MODLAND to develop a WWW site outlining a suggested strategy.

In addition, Alfredo Huete described a light aircraft remote sensing package developed for MODLAND Quick Airborne Looks (MQUALS). The package includes three aligned digital cameras (green, blue and near-infrared, 640x480 pixels), an albedometer, a 4-band calibrated radiometer and a GPS receiver. All data are stored in near-real time on a laptop computer. Initial NDVI images from the prototype camera showed expected patterns. The package was designed to be shipped to local small aircraft operators near validation sites for low cost site and reflectance characterization. The complete MQUALS system is designed to provide validation assessments within seven days of data collection. MODLAND personnel agreed to develop and prototype a data collection plan around the initial LAI/FPAR validation sites. Particular emphasis will be placed on 1) assessing radiometric qualities of the instruments, 2) overflying BigFoot sites in early post-launch timeframe, and 3) developing appropriate flight strategies for fast and useful scaling.

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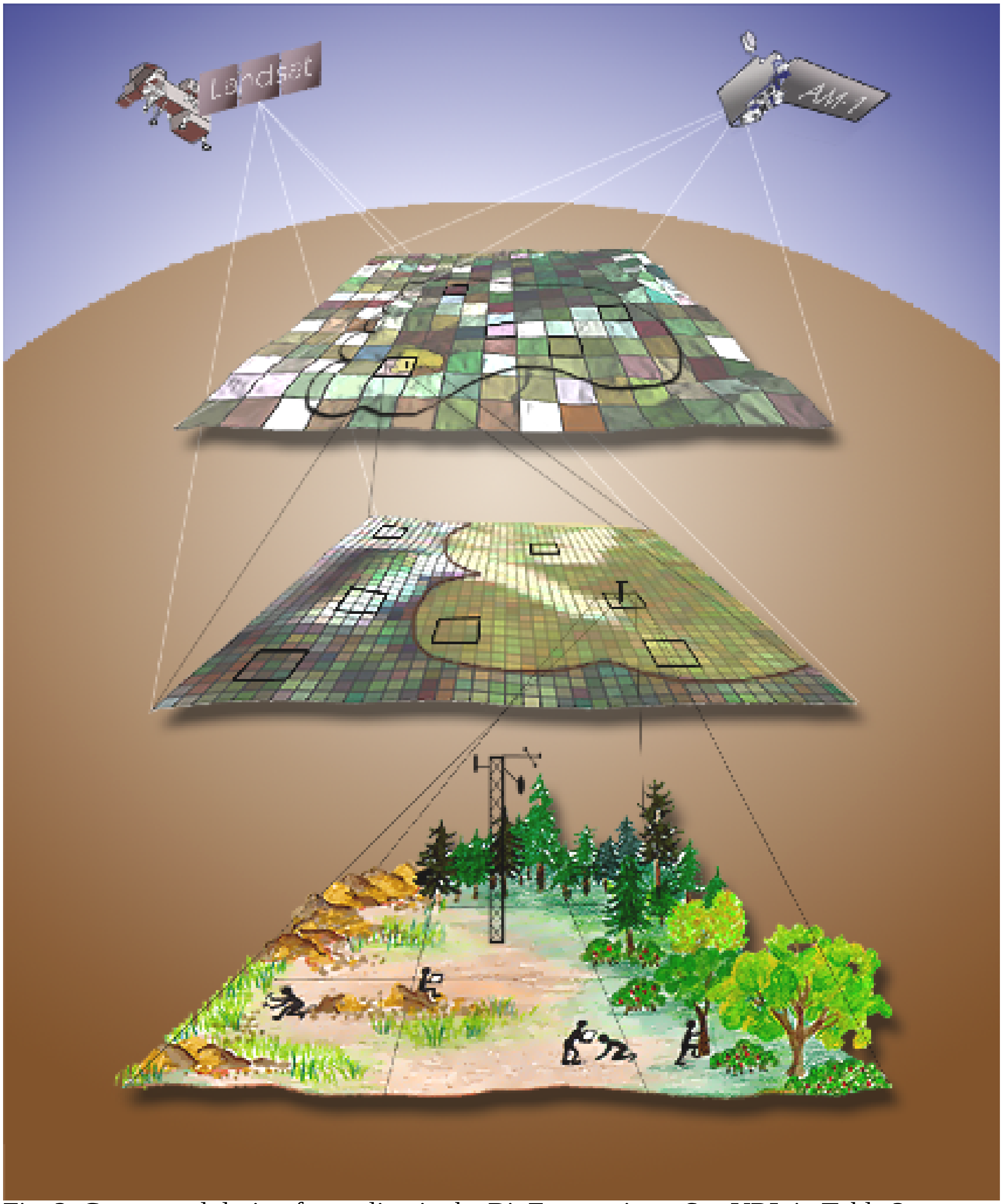

Fig. 2 Conceptual design for scaling in the BigFoot project. See URL in Table 3

Historical Data Mining

Because initial AM validation sites are relatively few, it was suggested that historical LAI/FPAR data (e.g., from FIFE, BOREAS) be analyzed and used to provide expected values and ranges for EOS product values. A number of extended data sources, such as the LTER network, were suggested. Possible roles for the EOS DAACs for archiving and distribution were also considered. Bill Emanuel and Jeff Privette agreed to bring this possible service to the attention of the ORNL DAAC.

Protocols and Data Dissemination

Finally, data and communication protocols were discussed. In particular, the respective roles of the ORNL and EDC DAACs, the EOS instrument teams, and the validation investigators in the coordinated validation system are under development. Representatives of the ORNL User Working Group and the EDC Scientific Advisory Panel (SAP) at the meeting agreed to address roles and responsibilities with their respective DAAC personnel. Moreover, pathways for educating the product user community on how to interpret validation results have yet to be developed. Participants briefly discussed possibilities including peer-reviewed publication, product metadata codes, and rasterized uncertainties for gridded products. This topic, together with timeliness issues, will be discussed in further communications. To further facilitate community access and involvement, the publication of a CD-ROM containing early Core Site validation data was also suggested.

EOS land product validation is being planned as part of a long-term implementation plan. Initial validation efforts will both estimate product accuracy and prototype validation scheme components. It is hoped the components currently planned, upon successful post-launch evaluation, will be substantially extended to provide more rigorous and comprehensive product evaluation.

We anticipate that the validation procedures started by the EOS instrument teams and validation investigators will act as a catalyst for broader involvement by the research community in product evaluation. Clear protocols for data collection and WWW archives and access will give all researchers a simple mechanism for participation. With the recent increase and planned launch of new moderate resolution sensors (e.g., VEGETATION, MODIS AM/PM, GLI, NPP, NPOESS) by different space agencies and the increased availability of higher order standard products, the benefits of standard measurement protocols and validation site data sharing are considerable. The CEOS Calibration/Validation Working Group is an obvious mechanism to expand the early developments and lessons learned in EOS land validation into a truly global validation initiative.

Table 3. WWW Site Addresses

Site	URL
BigFoot	www.fsl.orst.edu/spacers/bigfoot/plan.html
Committee for Earth Observation Satellites	ceos.esrin.esa.it
EOS Validation Program	eospso.gsfc.nasa.gov/validation/valpage.html
FLUXNET	daacl.ESD.ORNL.gov/FLUXNET
Global Climate Observing System	www.wmo.ch/web/gcos/gcoshome.html
Global Observations of Forest Cover	www.ccrs.nrcan.gc.ca/ccrs/tekrd/internet/gofc/gofce.html
Global Terrestrial Observing System	www.fao.org/gtos/Home.htm
Long Term Ecological Research	lternet.edu
EOS Land Validation Core Sites	modarch.gsfc.nasa.gov/MODIS/LAND/VAL/core_sites.html
MODLAND Validation	modarch.gsfc.nasa.gov/MODIS/LAND/VAL
Myneni’s LAI/FPAR Site	cybele.bu.edu/research/modismisr/
ORNL DAAC Validation Site	www-eosdis.ornl.gov/eos_land_val/valid.html